Land Use Dynamics in Iligan City Using Remotely Sensed Data and GIS

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Abstract

Iligan City is dubbed as the "Industrial Center of the South" as it hosts a number of major industries in the Philippines. One comparative advantage of the city as site for industries over other cities in Mindanao is its proximity to sources of power such as the Agus I to Agus VII Hydro-electric Power Plants operated by the National Power Corporation (NPC). As an industrial hub, Iligan City becomes one of the fastest growing urban centers in the country.

In this paper, satellite data taken in 1998 and in 2005 were compared to assess the change in land use pattern of the city to be able to project possible future land use change. The results indicate an increase in urban land area of 20%, an increase in agro-industrial area by 9% and a decrease in agricultural land by 6%. Urban growth is located along coastal areas and in some hinterland barangays.

The output of this research will serve as a tool to planners of Iligan City to guide them in setting policy directions of land development of the city.

Keywords: Land use dynamics; Remote sensing; GIS; Urban development; Econometric model; Iligan

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Introduction

The effects of globalization, population growth and advances in technology accelerate the urbanization process in most developing countries. During the second half of the twentieth century, the world urban population increased at an annual rate of 2.72% while the world population increased at an average annual rate of only 1.72% (United Nations Report, 2003).

The phenomenon of urban development is one of the major forces driving rapid change in land use, e.g., housing, industrial use, institutional use, roads, etc. (Wu et. al., 2006). In the United States, urban and built-up areas increased by 34% between 1982 and 1997 through conversion of cropland and forestland (Alig, et. al., 2004). In China, rapid urbanization in most cities caused unprecedented scale and rate of urban expansion thus leading to the loss of significant amount of agricultural land (Seto and Kaufmann, 2003). The issue on the conversion of agricultural land for urban development in China is of great significance because China`s per-capita land resource is far below the world`s average (Wu, et. al, 2006).

Land use and land cover changes are indicators of local environmental and ecological changes and this could further contribute to global changes (Meyer and Turner, 1991). Environmental degradation associated with urbanization has generated a debate on how much of the urban land cover has to be converted to developments. The change, especially the loss of agricultural land, has the potential to undermine the long- term harmony of humans and their environment. It is therefore important to determine the magnitude, pattern and type of land use and land cover changes to be able to project future extent of land development.

Iligan City, an industrial city south of the Philippines, is a medium-sized city but it hosts a number of industries, e.g., National Steel Corporation now Global Steel Corporation, Holcim Cement Corporation, Iligan Cement Corporation, Pilmico-Mauri Foods Corporation, GranExport Corporation, Mabuhay Vinyl Corporation, Northern Mindanao Power Corporation, National Power Corporation to name a few. Like other cities in the Philippines, Iligan City has also undergone rapid urbanization and economic growth since the 1990`s. One indicator of this rapid development is the increase in land value for subdivision lots from an average of U.S.$ 2 per sq.m. in 1990 to U.S. $ 50 per sq.m. in 2000. Fast change of land use happens to residential areas.

The pattern and magnitude of change of land use and land cover for Iligan City, or its urbanization dynamics, is investigated using satellite remote sensed data and geographic information system (GIS). Satellite remote sensing and GIS have been widely applied in identifying and analyzing land use and land cover change (Ehlers, et. al., 1990; Eastman and Fulk, 1993; Harris and Ventura, 1995; Jesen and Cowen, 1999; Chen, 2000; Seto and Kaufmann, 2003; Hathout, 2002; Wu, et. al, 2006). Satellite remote sensing provides multi-spectral and multi-temporal data that can be used to quantify the type, degree and location of land use change. GIS provides a flexible environment for displaying, storing and analyzing digital data necessary for change detection. Satellite remote sensing and GIS technology have been increasingly used in the examination of land use and land cover change especially those related to urban growth (Li and Yeh, 1998; Yeh and Li, 1999; Chen et. al, 2000; Qiong, et. al., 2006).

This study investigates the land use and land cover changes of Iligan City for periods from 1998 and 2005 using remote sensing data and GIS. The land use change projection for the next ten years studied. The method used can be applied to other cities in the Philippines that have urbanization dynamics similar to that of Iligan City.

Study Area

Iligan City is located at 8^{0}13’56” north latitude and 124^{0}13’ 54” east longitude. The City is the main entry of the Provinces of Lanao del Norte, Lanao del Sur and the Municipalities of the south-western part of Misamis Oriental (Figure 1).

Based on the national, Mindanao and regional-wide development perspective, the city's role will be the following (CDS, 2006):

- Industrial Center of Mindanao
- Sub-Regional Growth Center for Economic, Education, Service and Recreation
- Major City Component of Cagayan-Iligan Corridor (CIC)
- Major Player of Metro-Iligan Agri-Industrial Center
- Transshipment Point of Agricultural and Industrial products to Visayas and Mindanao Markets.

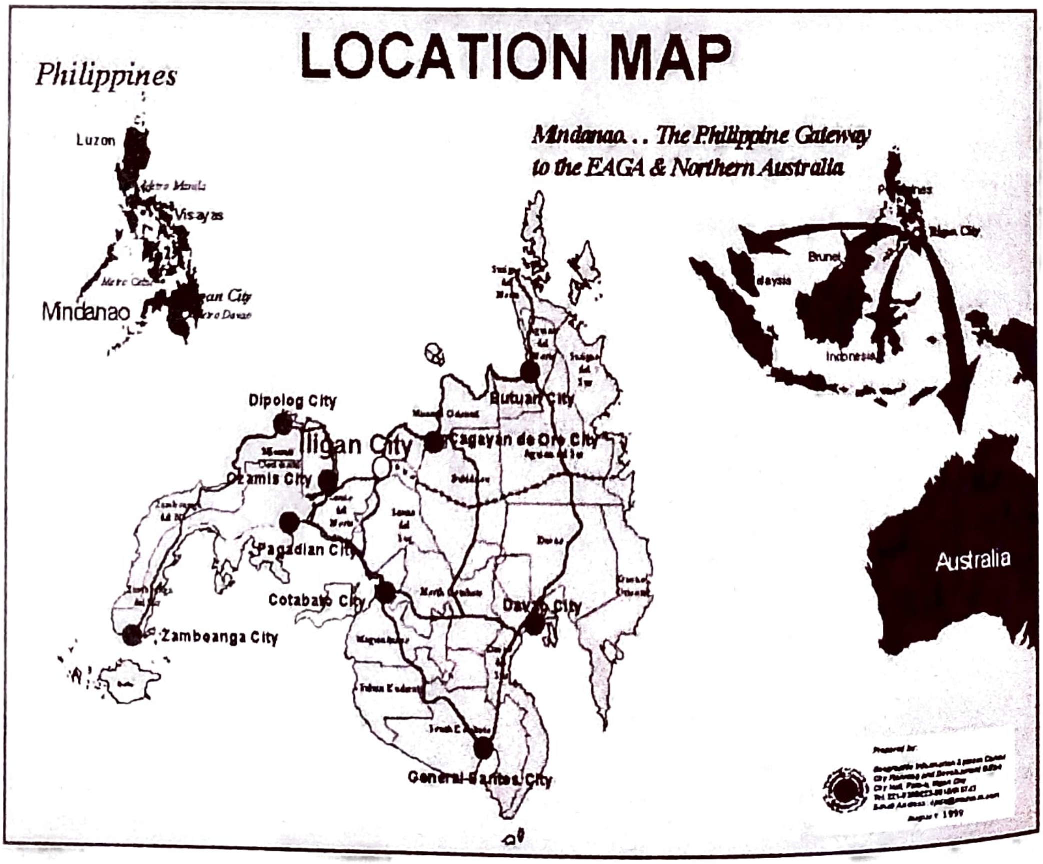

Figure 1. Location Map of Iligan City. (Source: City Planning and Development Office).

Iligan City has 44 barangays (Table 1 and Fig.2) covering a total land area of 81,337 hectares with the following land uses: urban that includes residential, commercial, industrial, institutional and other land uses for urban purposes; agriculture; forestry; and mining and quarrying. Barangay is the smallest political district of the Philippines. A group of barangays comprise a town or a city.

Table 1. Barangays Comprising Iligan City (City Planning Office)

Name of Barangay	**Area (Ha.)**	**Name of Barangay**	**Area (Ha.)**
1. Abuno	664.87	23. Pala-o	372.27
2. Acmac	109.78	24. Panoroganan	10,500.00
3. Bagong Silang	45.83	25. Poblacion	68.00
4. Bonbonon	424.13	26. Puga-an	1,043.47
5. Bunawan	2,195.20	27. Rogongon	35,555.29
6. Buru-un	1,000.72	28. San Miguel	59.39
7. Dalipuga	971.06	29. San Roque	131.62
8. Del Carmen	163.00	30. Santiago	110.42
9. Digkilaan	1,346.85	31. Saray	107.29
10.Ditucalan	77.56	32. Santa Elena	289.48
11.Dulang	3,000.00	33. Santa Felomina	503.92
12.Hinaplanon	551.54	34. Santo Rosario	24.26
13.Hindang	2,275.00	35. Suarez	338.43
14.Kabacsanan	594.45	36. Tambacan	48.18
15.Kalilangan	3,500.00	37. Tibanga	45.00
16.Kiwalan	914.23	38. Tipanoy	514.51
17.Lanipao	3,000.00	39. Tomas Cabili	264.38
18.Luinab	293.07	40. Tubod	320.67
19.Mahayahay	30.45	41. Ubaldo Laya	255.04
20.Mainit	7,325.00	42. Upper Hinaplanon	190.93
21.Mandulog	1,002.74	43. Upper Tominobo	400.53
22.Ma. Cristina	675.19	44. Villaverde	33.25
		Total Area	**81,337 Ha.**

Iligan City is generally highly urbanized along the coastal areas, with development extending along the north, south and eastern side of the City. The terrain is characterized by relatively narrow coastal plain and bounded to the south and east by hilly terrain that rises to elevations 100-200 meters above mean sea level (AMSL). In areas further inland, the terrain becomes more mountainous with steep slopes.

The climate of Iligan City is primarily tropical, with relatively high temperature, high humidity and abundant seasonal rainfall. The average annual temperature is 27.2°C, the average air humidity is 80%. January is the wettest month with an average rainfall of 221.4 mm while April is the driest month with rainfall of 50 mm (PAGASA).

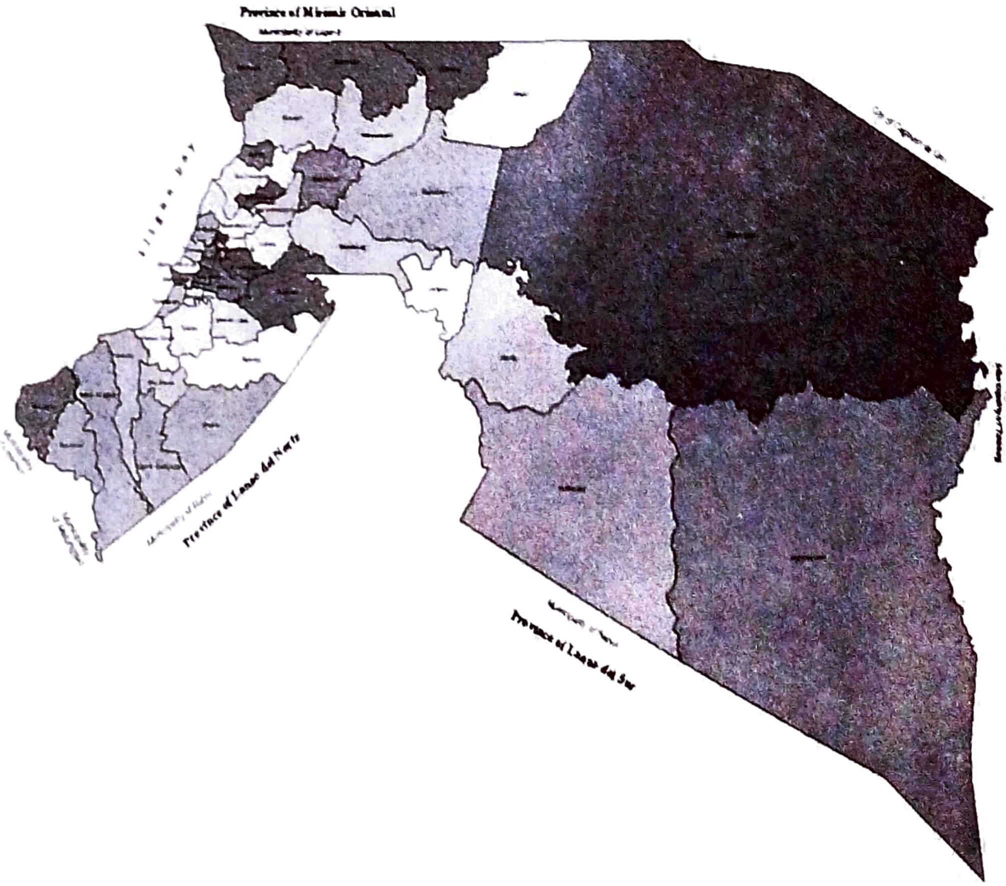

Figure 2. Administrative and Political Boundary Map of Iligan City (Source: City Planning and Development Office) Methods

Methods

Land use patterns from the SPOT satellite image in 1998 (Fig. 3) and the 2005 satellite image from Google Earth (Fig. 4) were examined and analyzed. Another satellite image from LandSat multispectral scanner (MSS) should have been analyzed to come up with at least three data sets to model land use change of the study area. Due to cost limitation to acquire the satellite image, the LandSat MSS satellite data of 1988 was discarded. Four major types of land cover are used for the purpose of characterizing urban sprawl: built-up area, agro-industrial, agricultural and water body. The built-up area includes residential buildings, commercial facilities, shopping centers, highways and streets and associated properties and parking lots.

Each of the satellite images are enhanced and geo-referenced to the Philippine coordinate system, particularly the Luzon Datum.

The maximum likelihood method is used to validate the land use classification. Both statistical and geographical analyses of feature are conducted to discriminate each class for land classification. The feature selection process is reduced to the number of bands (visible to near infrared ranges) to be processed in the database, but, should not affect the classification accuracy (Jensen, 1996). Field surveys of existing land use maps are gathered for field checking using the global positioning system (GPS).

In order to estimate the location and rate of land use change, the land use maps were overlain with the administrative boundary map constructed in GIS environment.

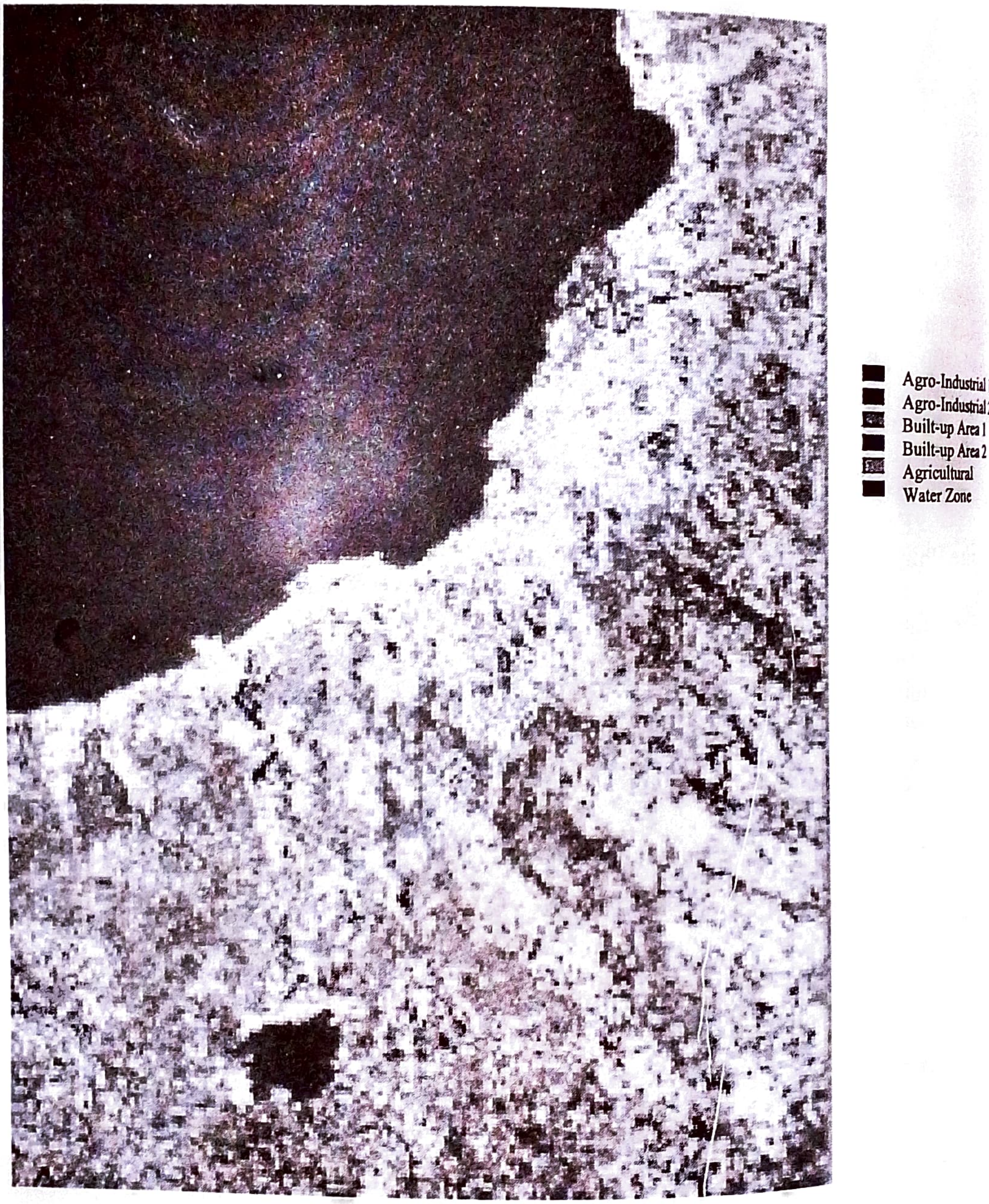

Figure 3. 1998 Land Cover from SPOT Image

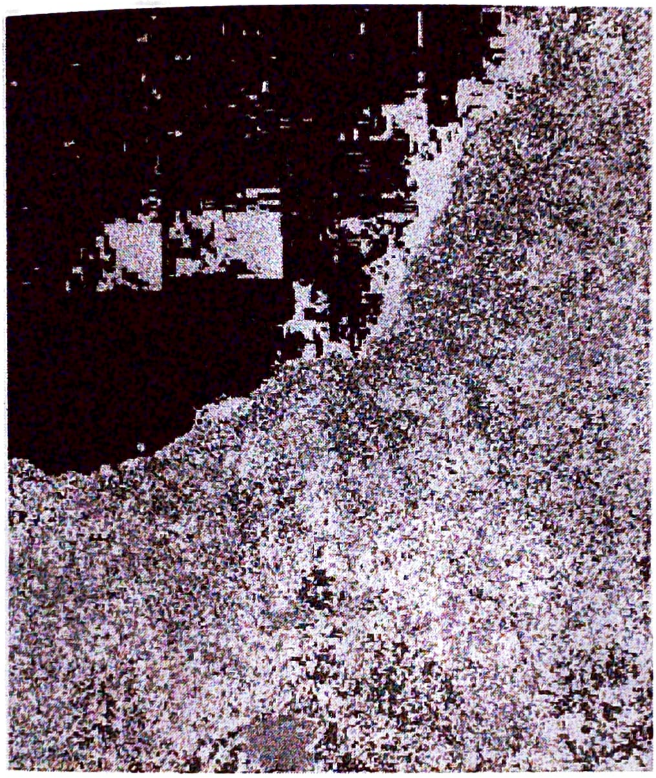

Figure 4. 2005 Land Cover from Google Earth

Results and Discussions

The land cover change analysis shows altered land cover from 1998 to 2005 as shown in Table 2.

Table 2. Land Use Area Measurement Within Iligan City from 1998 to 2005

Land Use Classification	1998		2005		Change: 1998-2005	
	Area (ha)	Area (%)	Area (ha)	Area (%)	Area (ha)	Area (%)
Agro-Industrial	4 076.6	8.53	4 440.2	9.08	363.6	8.92
Agricultural	16 578.6	34.68	15 609.7	32.66	-968.9	-5.84
Built-up Area	4 485.4	9.39	5 389.4	11.49	904.0	20.15
Water Zone	22 651.5	47.40	22 352.4	46.77	-299.1	-1.32

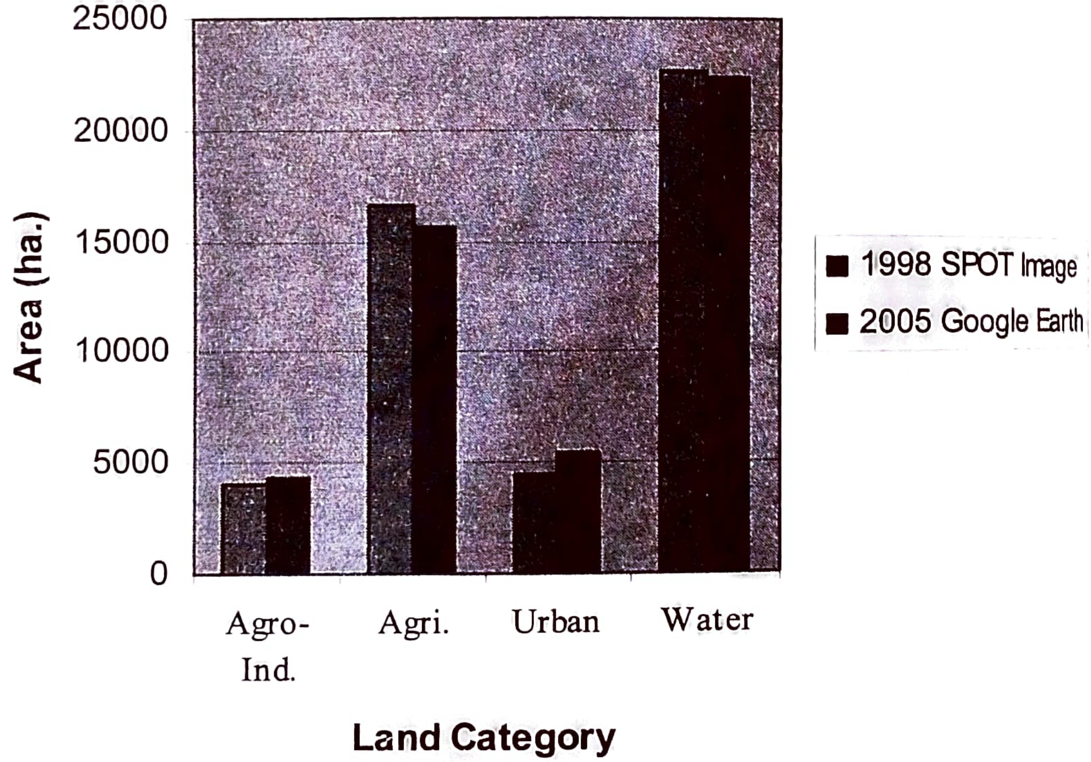

Figure 5. Land Cover Change from 1998 to 2005

Figure 5 shows an increase in Agro-Industrial Land (9%%) and Urban Land Areas (20%) and a corresponding decrease in Agricultural Land (6%) and Water Zone Areas(1.3%). The highest change is the increase in urban land areas, which is relatively high. The 2005 Google Earth satellite image may not be properly prepared. On the other hand, a study conducted by Wu, et.al. (2006) revealed that one tangible factor in the increase in urban areas is the increase in population. By looking at the urban population of Iligan City, population increases at the rate of 23.24% from period 1998 to 2005 as shown in Fig. 6.

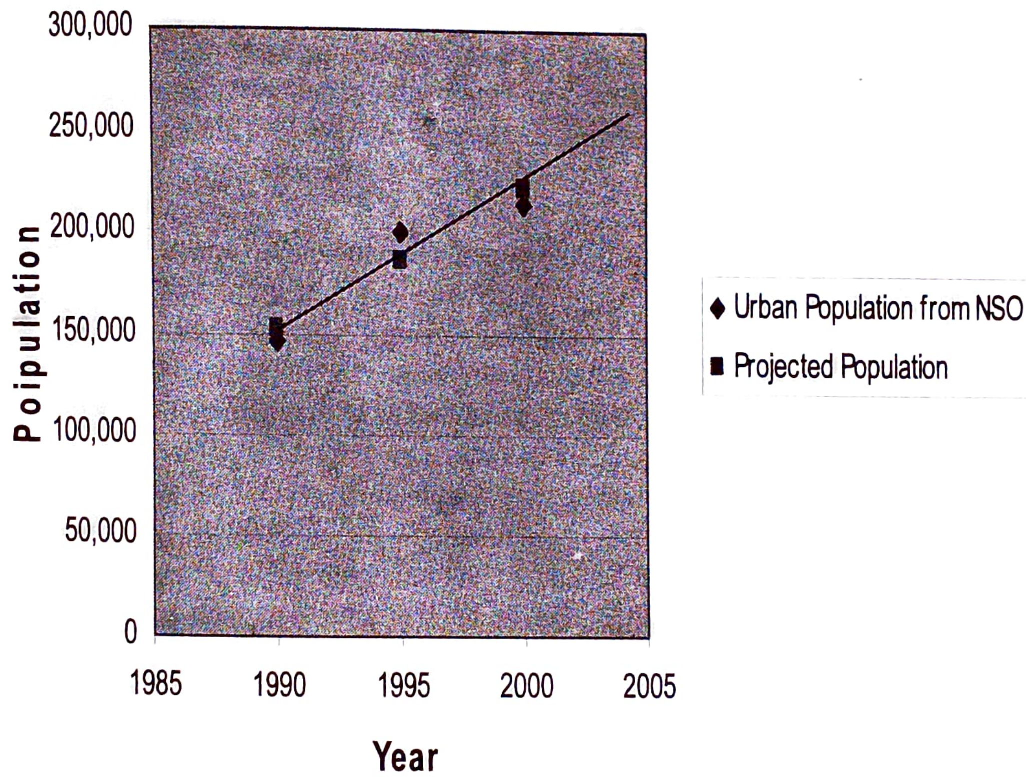

Figure 6. Urban Population of Iligan City (NSO)

The high increase in urban land could partly be explained by high increase in urban population.

The overlay with the administrative map reveals spatial occurrence of urban expansion along coastal areas and developments in Barangays Upper Tominobo, Tipanoy, Abuno, Pugaan of which some inhabited parts have elevation of 200 m AMSL.

If this trend in the increase in urban land will be left unchecked by the City Planners and Administrators, in 2015 or about 17 years from 1998, urban land area will increase to 6,682 ha. or an increase in urban land area to 49%. The urban land development will then exceed about

700 hectares from the present land allocation of 6,000 hectares for urban land, the Iligan City Zoning Ordinance of 1975.

Recommendations

Further study may be conducted to include at least satellite data in the 1970's and 1980's to be able to obtain appropriate data to model and to project possible future land use change. The earlier attempt to model land use change based on land rent maximization theory may be studied.

Land Rent Maximization is an econometric model which was tested by Alig, et. al. (2004) to examine land use change in the US landscape. This kind of econometric model was also tested by Wu, et. al. (2006) in the case of urban land use change in Beijing. Economic and demographic variables are used as proxies for rents from urban land and the cropland protection ordinance was used as a dummy variable.

The dependent variable in the regression model is the urban land area (ULA) in hectares. The independent variables in the regression model are the non-agricultural population (10,000) to account for the impact that population growth has on the expansion of urban land, per capita income (US $1) of urban population to account for the per capita land consumption rise with real personal income, per capita income (US $1) of rural population to account for urban land consumption which is inversely related to opportunity costs of forgone agricultural production, and the Network of Protected Agricultural Areas for Agricultural Development (NPAAAD) as a dummy variable to account for the 1994 agricultural land protection ordinance.

$$ULA = \beta_0 + \beta_1 \text{(non-agricultural population)} + \beta_2 \text{(urban per capita income)} + \beta_3 \text{(rural per capita income)} + \beta_4 \text{(NPAAAD)} \quad (2)$$

where $\beta_0, \beta_1, \beta_2, \beta_3, \beta_4$ are the coefficients

Area data of urban land for analysis will come from the four classified images from 1975 to 2005. Data of population and per capita income will come from the National Statistics Office (NSO) and the Office of the City Government of Iligan.

Since Iligan City is also part of the watershed area of the NPC for the sustainability of its seven series of hydro-electric water plants, it is also recommended to study the potential impacts to forest and watershed integrity as a result of urban land developments.

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